and carry out a similar excursion on a more extended scale. Dr. Marshall described the echinoderms, molluscs, annelids, and crustaceans taken.

PROF. PALMIERI has noted for the present year great anomalies of temperature. The degree of heat observed at the Vesuvius Observatory is unprecedented, having reached 34° C., and the mercury has fallen as low as − 7° C. This low temperature has never been reached once before, even in January and February, in the twenty-five years during which the observatory has been established.

THE Emperor of Brazil has formed a commission charged with the determination of geographical positions in the empire, and the first work of this commission is just published. It contains an account of the determination of the longitude and latitude of Barra de Pirahy. Geodesic operations are continued for localities situated on the prolongation of the Santos railway, and also on the parallel (10° in length) destined to join Rio to the great meridian of the empire, which will be measured by the commission.

Die Natur of September 17 contains an interesting collection of some of the myths and stories which constitute the folk-lore of the Australian aborigines.

IN the Anthropological Section of the Havre meeting of the French Association M. Gustave Lagneau exhibited an ethnographic map of France, on which he has attempted to indicate, in accordance with historical and ethnographical data, the division, juxtaposition, superposition and mixture of the various ethnical elements which have contributed to the formation of the present population of the country.

OF the many natural history societies in the United States but one, so far as is known, is composed almost entirely of Germans, the proceedings of which are published in the German language. This is the Naturhistorisches Verein, of Milwaukee, Wisconsin, of which the annual report for 1876–77 has just been published. This society is organised in five sections—zoology, botany, mineralogy, geology, and ethnology—holds regular meetings, and has quite a large active membership.

A GENERAL inventory has been taken by the French ministry of all the public libraries of France. More than 200 towns have been found to possess each a library numbering from 10,000 to 20,000 volumes.

A SWEDISH paper just received publishes an interesting article under the heading, "Why is the Climate of Europe growing Colder?" The article states that in the Bay of Komenok, near Koma, in Greenland, fossil and very characteristic remains of palm and other trees have been discovered lately, which tend to show that in these parts formerly a rich vegetation must have existed. But the ice period of geologists arrived, and, as a consequence of the decreasing temperature, this fine vegetation was covered with ice and snow. This sinking in the temperature, which moved in a southerly direction, as can be proved by geological data, *i.e.*, the discovery of fossil plants of certain species, seems to be going on in our days also. During the last few years the ice has increased far towards the south; thus between Greenland and the Arctic Sea colossal masses of ice have accumulated. On European coasts navigators now frequently find ice in latitudes where it never existed before during the summer months, and the cold reigning upon the Scandinavian peninsula this summer results from the masses of ice which are floating in the region where the Gulf Stream bends towards our coasts. This is a repetition of the observations made in the cold summer of 1865. The unaccustomed vicinity of these masses of ice has rendered the climate of Iceland so cold that corn no longer ripens there, and the Icelanders, in fear of a coming famine and icy climate, begin to found a new home in North America.

PROF. NORDENSKJÖLD'S voyages seem to have been of service in opening up a sea-route to Siberia for commerce. A vessel belonging to M. Sidoroff, Capt. Schwanenberg, arrived at Vardö on September 16, after a passage of twenty-one days from the mouth of the Yenisei; and the steamer *Trazer*, belonging to M. Sibiriakoff, Capt. Dahlmann, which sailed from Bremen on July 28 for the mouth of the Yenisei, returned to Hammerfest on September 24.

A FIRE in Washington has destroyed the greater part of the Patent Office Museum, with thousands of patent models, many of great value.

WE notice among Messrs. Churchill's announcements for the forthcoming season: "A Handbook of Analysis of Water, Air, and Food, for the Medical Officer of Health," by Cornelius B. Fox, M.D., M.R.C.P., Medical Officer of Health for Central, East and South Essex; "Parasites: an Introduction to the Study of the Entozoa of Man and Animals, including some Account of the Ectozoa," by T. Spencer Cobbold, M.D., F.R.S., F.L.S., Professor of Helminthology in the Royal Veterinary College; and a "Student's Guide to the Anatomy of the Joints," by Henry Morris, M.A., M.B., F.R.C.S., Assistant-Surgeon to and Lecturer on Anatomy at the Middlesex Hospital.

THE additions to the Zoological Society's Gardens during the past week include a Grivet Monkey (*Cercopithecus griseoviridis*) from West Africa, a Nisnas Monkey (*Cercopithecus pyrrhonotus*) from Nubia, presented by Mr. W. D. James; a Green Monkey (*Cercopithecus callitrichus*) from West Africa, presented by Mr. W. W. Stead; a Macaque Monkey (*Macacus cynomolgus*) from India, presented by Mr. J. F. Greenwood; a Capybara (*Hydrochœrus capybara*) from South America, presented by Mr. W. Smith; a Peregrine Falcon (*Falco peregrinus*), European, an African Buzzard (*Buteo tachardus*) from Africa, presented by the Rev. W. Willimott; a West African Python (*Python sebæ*), a Royal Python (*Python regius*) from West Africa, presented by Mr. J. J. Kendall; a Goffin's Cockatoo (*Cacatua goffini*) from the Fiji Isles, an Ariel Toucan (*Ramphastos ariel*), a Maximilian's Aracari (*Pteroglossus wiedi*), two Blue-bearded Jays (*Cyanocorax cyanopogon*), two West Indian Rails (*Aramides cayennensis*) from South America, deposited; two Upland Geese (*Bernicla magellanica*) from the Straits of Magellan, three Andean Geese (*Bernicla melanoptera*), two Slaty Coots (*Fulica ardesiaca*) from Peru, purchased; an Axis Deer (*Cervus axis*), a Yellow-footed Rock Kangaroo (*Petrogale xanthopus*), born in the Gardens.

THE DIRECT PROCESS IN THE PRODUCTION OF IRON AND STEEL[1]

IN mixing comparatively rich iron ore in powder, with about twenty-five per cent. of its weight of pounded coal, and in exposing this mixture for some hours to the heat of a common stove or of a smith's fire, metallic iron is formed, which, on being heated to the welding point, on the same smith's hearth, may be forged into a horse-shoe of excellent quality. The admixture with the ore of some fluxing materials, such as lime or clay, will, in most cases, be of advantage to rid the iron of adherent slag.

The simplicity of this process is such that it naturally preceded the elaborate processes now in use for the production of iron and steel upon a gigantic scale, nor can it surprise us to find that attempts have been made from time to time down to the present day, to revert to the ancient and more simple method. It can be shown that iron produced by direct process is almost chemically pure, although the ores and reducing agent employed may have contained a considerable percentage of phosphorus,

[1] Some Further Remarks regarding the Production of Iron and Steel by Direct Process Paper read at the Newcastle Meeting of the Iron and Steel Institute, by C. William Siemens, D.C.L., F.R.S., President.

sulphur, and silicon, and that, if freed from its adherent slag, it furnishes a material superior in quality and commercial value to the ordinary iron of commerce.

The practical objections to the direct process, as practised in former days, and as still used to a limited extent in the United States of America and in some European countries, are that—

1. Very rich ores only are applicable, of which about one-half is converted into iron, the remainder being lost in forming slag.

2. The fuel used is charcoal, of which between three and four tons are used in producing one ton of hammered blooms.

3. Expenditure of labour is great, being at the rate of thirty-three men, working twelve hours, in producing one ton of metal (see Percy). Iron produced by direct process in the Catelon forge is therefore expensive iron, and could not compete with iron produced by modern processes except for special purposes, such as furnishing melting material for the tool steel melter.

But, it may be asked, could the advantages of the direct process not be combined with those of modern appliances for the production of pure and intense heats, and for dealing with materials in large masses, without expenditure of manual labour, and cannot chemistry help us to larger yields and the faculty of using comparatively poor and impure ores?

A careful consideration of these questions led me to the conclusion, some years ago, that here was a promising field for the experimental metallurgist, and that I possessed some advantage over others in the use of the regenerative gas furnace as a means of producing the requisite quality of heat without the use of charcoal and blowing apparatus. I engaged, accordingly, upon a series of experimental researches at my sample steel works, at Birmingham, and, in 1873, I had the honour of submitting the first fruits of these inquiries to the Iron and Steel Institute, in a paper entitled "On the Manufacture of Iron and Steel by Direct Process." Encouraged by the results I had then obtained, I ventured with some others upon some larger applications, the principal one of which has been one at Towcester, in Northamptonshire.

Viewed by the light of present experience, it would have been wiser to have fixed upon another locality with fuel, skilled labour, and better ores within easy reach; but in extenuation of the error committed, it may be urged that the site was fixed by force of circumstances rather than by selection, the chief temptation being an ample supply of small Northamptonshire ore at a very low cost. It was, however, soon discovered that this ore, although capable of producing iron of good quality, was too poor and irregular in quality to yield commercial results unless it was mixed with an equal weight of rich ore, such as pottery mine, Spanish ore, or Rollscale, all of which, as well as the fuel, are expensive at Towcester, owing to high rates of carriage. It is in consequence of these untoward circumstances that the works at Towcester have not been completed by the addition of rolling mills, the intention being to transfer the special machinery ultimately to existing ironworks when the process has been sufficiently matured for that purpose.

The Towcester Works were visited, in the autumn of last year, by two eminent metallurgists, Professors von Tunner, of Leoban, and Akermann, of Sweden, who have published the results of their observations in separate reports.[1] The results noted down by Mr. von Tunner are referred to by our past-president, Mr. I. Lowthian Bell in his paper on the "Separation of Carbon, &c.," which was read in March last, and will be discussed at the Newcastle meeting. The criticisms contained in these publications are conceived in the fairest possible spirit, and form indeed a most valuable record of the progress achieved up to that time, but they furnish me with an inducement to break silence sooner than I had intended, regarding the further progress which has been effected, and the conclusions I am disposed to draw from past experience regarding the direct process of the future.

The leading idea which guided me in these was to operate upon such mixtures of ores, fluxes, and reducing agents as would, under the influence of intense heat, resolve themselves forthwith into metallic iron and a fluid cinder, differing essentially from the methods pursued by Chenat, Guilt, Blair, and others, who prepare spongy metal in the first place by a slow process which is condensed into malleable iron or steel by after-processes, but assimilating to some extent to the process first proposed by Mr. Wm. Clay. In my paper of 1873 I described two modes of effecting my purpose, the one by means of a stationary, and the other by means of a rotative furnace chamber, the former being applicable chiefly where comparatively rich ores are available, and the latter for such poorer ores as occur near Towcester.

[1] Das Eisenhüttenwesen von L. Ritter von Tunner, Wien, 1870.

At the Towcester Works three rotative furnaces have been erected, two of them with working drums seven feet in diameter and nine feet in length, and the third of smaller dimensions. The gas flame both enters and passes away from the back end of the furnace, leaving the front end available for the furnace door, which is stationary. The ends of the furnace chamber are lined with Bauxite bricks, and the circumference with ferrous oxides, resulting from a mixture of furnace cinder enriched with roll scale or calcined blackband in lumps. About 30 cwt. of ore mixed with about 9 cwt. of small coal having been charged into the furnace, it is made to rotate slowly for about two and a half hours, by which time the reduction of the metal should be completed, and a fluxed slag be formed of the earthy constituents containing a considerable percentage of ferrous oxide. The slag having been tapped, the heat of the furnace and the speed of rotation are increased to facilitate the formation of balls, which are in due course taken and treated in the manner to be presently described.

These balls contain on an average seventy per cent. metallic iron and thirty per cent. of cinder, and upon careful analysis it is found that the particles of iron, if entirely separated from the slag, are pure metal, although the slag may contain as much as six per cent. and more of phosphoric acid, and from one to two per cent. of sulphur. In shingling those balls in the usual manner the bulk of the cinder is removed, but a sufficient residue remains to impart to the fracture a dark appearance without a sign of crystalline fracture. The metal shows in being worked what appears to be red shortness, but what should be termed slag shortness. In repiling and reheating this iron several times this defective appearance is gradually removed, and crystalline iron of great purity and toughness is produced, but a more ready mode of treatment was suggested by Mr. Samuel Lloyd, one of my co-directors in the Towcester Company, in reverting to the ancient refinery or charcoal hearth. The balls as they came from the rotator are placed under the shingling hammer and beaten out into flat cakes not exceeding an inch in thickness. These are cut by shears into pieces of suitable size and formed into blooms of about 2 cwt. each, which are consolidated under a shingling hammer and rolled into bars.

The bars have been sold in Staffordshire and Sheffield at prices varying from 7*l.* to 9*l.* per ton, being deemed equal to Swedish bar as regards toughness and purity.

It may therefore be asserted as a matter of fact that iron and steel of very high quality may be produced from ores not superior than Cleveland ores by direct process, but the question remains at what cost this conversion can be effected. The experimental works at Towcester are, unfortunately, not sufficiently complete to furnish more than the elements upon which the question of cost may be determined, the principal reasons being that the one reheating furnace and a 30 cwt. hammer at the works are not sufficient to deal with the iron produced by the three rotators, that the iron has to be finished at a rolling-mill elsewhere, and that transports weigh heavily upon the cost of production. The principal factor in the calculation of cost is unquestionably the rotator. [A table furnishes the working result of eighteen consecutive charges as taken from the charge-book.] The mixture of ore consisted for each charge of 12 cwt. of Towcester ore (containing about 38 per cent. metallic iron) mixed with 8 cwt. of calcined Great Fenton ore, 1 cwt. of tap cinder, 1 cwt. of limestone, and 6½ cwt. of small coal. The time occupied for each charge was three hours fifty-seven minutes, or say four hours, and the yield of hammered blooms was on an average 6 cwt. 2 qrs. 13 lbs., whereas the metal contained in each charge amounted (by estimate) to 9 cwt., showing a loss of 25 per cwt. This loss is, however, partially recovered in using a portion of the cinder again in succeeding charges, but the proportion of cinder that may be used again with impunity depends upon the amount of impurities, namely, of phosphorus, sulphur, and alumina contained in the ore. The coal used in the producers amounted to two tons per ton of hammered blooms produced, and in pricing the materials used and labour engaged upon the work, the table—prepared by the manager at the works—gives 3*l.* 8*s.* as the cost per ton of hammered blooms. To this must be added for repairs and general expenses, and the cost of rolling the hammered blooms into bars, which in the case of Towcester practice are very heavy, but of which an experienced iron-master would form his own estimate. The cost of working the metal in the hollow fires is also not included, and this may be taken to add from 25*s.* to 30*s.* to the ton. The refined iron so produced will, therefore, cost from 5*l.* 5*s.* to 5*l.* 10*s.* per ton.

Other tables give the analysis of irons produced from various

descriptions of ores, and Kirkaldy's tests of the mechanical properties of the iron; but it should be understood that these tests were taken with a view rather to test various modes of manufacture than to show high results. Only a small proportion of the samples had been subjected to the refinery process, and the variable percentage of phosphorus may be taken really as indicative of the extent to which the cinder had been removed from the metal.

Another table gives the analysis of slags produced in the process. These are, no doubt, rich in iron, but it must be remembered that in the case of comparatively pure ore they can be used almost entirely in succeeding charges, and that in the case of ores containing much sulphur and phosphorus they are the recipients of those impurities—in the same way as the puddling cinder carries off the same impurities in the puddling furnace—and thus serve a useful end.

If rich ores, such as hematites, are available, it is more advantageous to use a stationary furnace and to modify the process as follows:—

A mixture of pulverulent ore mixed with a suitable proportion of fluxing materials and reducing agent is prepared, and from four to five tons of it is charged from a charging platform into the heated chamber to the depth of some twelve to fifteen inches. But before charging the mixture some coke dust or anthracite powder is spread over the bottom and sides of the chamber to protect the silica lining of the same. The heat of the furnace is thereupon raised to a full welding heat, care being taken that the flame is as little oxidising as possible. The result is a powerful superficial action upon the mixture or batch, causing simultaneous reduction of the ore and fusion of the earthy constituents. In the course of two hours a thick skin of malleable iron is formed all over the surface of the mixture, which, on being withdrawn by means of hooks, is consolidated and cleared of cinder under a hammer, and rolled out in the same heat into rough sheets or bars, to be cut up and finished in the refinery furnace or charcoal hearth. One skin being removed, the furnace is closed again, and in the course of an hour and a half another skin is formed, which, in its turn, is removed and shingled, and so on until, after three or four removals, the furnace charge is nearly exhausted. A fresh charge is then added, and the same operation continued. Once every twelve hours the furnace should, however, be cleared entirely, and the furnace lining be repaired all round.

The shingled metal so produced forms an excellent melting material for the open-hearth or Siemens-Martin process; but if ores both rich and free from sulphur and phosphorus are used, together with roll and hammer scale, which forms an admirable admixture, I simplify the process still further in causing the fusion to take place in the reducing furnace.

The furnace having been charged with say five tons of batch, the heat is allowed to ply on it for four or five hours, when about two tons of hematite pig iron are charged upon the surface by preference in a heated condition. The pig metal on melting constitutes a bath on the surface of the thick metallic skin previously formed, and gradually dissolves it on the surface while it is forming afresh below, and in the course of from three to four hours the whole of the materials charged are rendered fluid, consisting of a metallic bath with a small percentage of carbon, covered with a glassy slag containing about 15 per cent. only of metallic iron. The carbon of the bath is thereupon brought down to the desired point of only about 1 per cent. of carbon and spiegeleisen or ferro-manganese is added, and the metal tapped in the usual manner. By these means the direct process of making cast steel is carried to a further limit than I have been able to accomplish before, and no difficulty has presented itself in carrying it into effect. The steel so produced is equal in quality to that produced by the open hearth process as now practised. If light scrap, such as iron and steel turnings or sheerings, are available, these may be mixed with advantage with the batch to increase the yield of metal.

These are, in short, the more recent improvements in the direct process of producing iron and steel which I have been able to effect, and which I should have been glad to lay before the Iron and Steel Institute in a more complete form than I am able to do at the present time.

THE AMERICAN ASSOCIATION AT NASHVILLE

As we have said already, while the Nashville Meeting of the American Association could not be called a brilliant one, most of the papers read were of substantial importance, and show that a large amount of valuable scientific work is being carried on in the United States. The number of visitors does not appear to have been up to the usual mark, mainly, we believe, on account of the great heat which prevailed at Nashville, but among those present were many of the most prominent men of science in America. The reception by the authorities of the State and city was all that could be desired, and the arrangements as to excursions, entertainments, and public lectures were in every way satisfactory.

The Western Union Telegraph Company, which has a Telegraphic Station in the building where the Association met, tendered the use of its wires free for all members so far as related to domestic affairs.

It is customary at the meetings of the American Association for each of the vice-presidents to give a public lecture; we give a long abstract of the lecture by Prof. O. C. Marsh, the importance of which cannot be overrated. We have already referred briefly to Prof. Pickering's paper on the Endowment of Research. The first obstacle encountered, he said, was the opinion widely maintained, even by scientific men, that the original research of a country was natural, and that it was useless to try to force it. We might as well say that music and art were natural growths. What should we have of ancient art were it not for the encouragement of many ancient rulers? In later days how would art and literature have thrived had it not been for the support of the public in purchasing books, &c. With the man of science it was different. There was generally little or no pecuniary reward for his success. The consequence was he was obliged to engage in some other occupation, generally teaching, which still allowed a little time for research. If these same men were allowed to devote their entire energies to investigation, and were aided by the necessary appliances, far more would be accomplished. The solution of the matter was organisation, the carrying out of a plan by which researches should be rendered as systematic as the process of mechanical arts. They had first the munificent bequest of one of the first presidents of the Association. The income of the Bache fund amounted to 2,000 dols. or 3,000 dols. Second was the Rumford fund, originally intended for giving medals in light and heat, but now largely applied to aiding investigation in these sciences. Besides these were many indirect aids. The paper then gave a plan of an institution for making researches: First, a president; second, a corps of investigators of acknowledged scientific ability; third, a large corps of assistants, whose duty it should be to carry out work laid out for them; fourth, workmen, such as mechanics. He then went on to describe a building such as would be as perfect as possible for the institution. It was useless to hope for architectural beauty, as the effect would be spoiled by attachments made to the exterior. No more common mistake was made than in wasting money which should be used for equipment. They had too many colleges with far too little endowment. Such an institution, added to a college, would prove of great advantage.

At a general evening meeting, Prof. Newcomb (president) spoke at some length, extemporaneously, on the two recent important discoveries made by American men of science, viz., the existence of oxygen in the sun, by Prof. Draper, and the satellites of Mars, by Prof. Hall. At the same evening meeting Prof. A. R. Grote, of Buffalo, read a sketch of a scheme for an international scientific service formed by the union of the various civilised governments and national scientific societies, for the carrying out of such scientific work as all the world is interested in. Under the auspices of such an association "all extra-limital, astronomical, geographical, and biological expeditions would be fitted out and directed to those places which would be most fruitful for the particular purpose."

Of the papers read in the various sections we are able, at present, to give little else but the titles. In Section A, which includes Mathematics, Astronomy, Physics, Chemistry, and Mineralogy, the following, among other papers were read:—*On a New Type of Steam Engine theoretically capable of utilising the full Mechanical Equivalent of Heat Energy, and on some points of Theory indicating its Practicability*, by Prof. R. H. Thurston; *Mechanics of the Flight of Birds*, by Mr. A. C. Campbell. An interesting paper in this section by Prof. Forshey, treated of *The Physics of the Gulf of Mexico and of its Principal Affluent the Mississippi*; the author brought together many important data concerning what he styled "the cis-Atlantic Mediterranean." Another paper in this section by Prof. Mendenhall, was *On Measurement of the Wave-length of the Blue Line of the Indium Spectrum.*